SLAC-PUB-3110
April 1983
(N)

21.10 Dr, 21.30 +y, 21.40 +d, 27.10 +h

NUCLEON-NUCLEON SCATTERING CONTRIBUTION TO THE TRITON BINDING ENERGY*

H. Pierre Noyes
Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94305

We conjectured in 1972 that much of the dynamics of few nucleon systems could be computed from the on-shell nucleon-nucleon scatterings provided that a consistent few body theory using this input could be constructed.[1] Such a "Zero Range Scattering Theory" has been shown[2] to lead to unitary three and four particle scattering amplitudes provided only the two particle amplitudes have no singularities other than bound state poles when continued to negative energies, which restricts the theory to Castillejo-Dalitz-Dyson solutions of the Low equation. Since the two-nucleon amplitudes are most easily represented by models with a "left-hand cut" representing meson exchange, or "potential" effects, the theory is not immediately applicable to nuclear physics.

We extend the model by writing the off-shell amplitude $t(z-\tilde{p}^2)$ which drives the Faddeev equations as

$$t(z-\tilde{p}^2) = \theta(z-\tilde{p}^2)\int_{m_\pi/2}^{\infty}\rho(\sigma)d\sigma/(\tilde{\sigma}^2+z-\tilde{p}^2)-\left(\frac{2}{\pi}\right)\int_0^{\infty} sin^2\delta_k dk/(\tilde{p}^2+\tilde{k}^2-z)-\frac{N^2}{(\tilde{p}^2-\epsilon-z)}$$

This amplitude retains full off-shell unitarity and still leads to unitary on-shell three particle amplitudes. This amounts to keeping any unitary two-nucleon amplitude on-shell and restricting the analytic continuation to negative energies to the term which represents the correct continuation of the two particle total partial wave cross section; the meson exchange or "potential" contributions are eliminated in the unphysical region, thus excising the "left-hand cut". We compute this term $\int_0^\infty dk\ sin^2\delta_k/(\tilde{p}^2+\tilde{k}^2-z)$ using (a) the effective range approximation, (b) the on-shell phase shift of the Yamaguchi model, (c) a four parameter fit to the empirical nucleon-nucleon phase shifts $k\ ctn\ \delta_k = A + Rk^2 + Ck^4/(1-k^2/k_0^2)$ where k_0 is the momentum where δ_k vanishes and (d) at least squares fit to the empirical values of $sin^2\delta_k$. Using this model in the zero range Faddeev equations for the three nucleon system our preliminary results[3] show that the on-shell scatterings bind the triton with about 2.5 MeV and are insensitive to the details of the fit. We have therefore answered the question posed in 1972. The cancellation between kinetic and "potential" energies in the triton bound state, which in a conventional theory are of the order of 50-100 MeV, can be explained to about 10% simply in terms of the on-shell scatterings.

There are two interesting ways to extend the model to explain the empirical triton binding energy. One is to add a direct three body scattering term with a pole at the triton binding energy whose residue can be adjusted to fit the $^2S_{1/2}\ n-d$ scattering length. This will provide an interesting model for low energy $n-d$ scattering and breakup, normalized at threshold. An alternative is to introduce an off-shell extention of the empirical amplitude consistent with the constraint emposed by the Low equation[1] which leaves the on-shell scattering untouched. This amounts to adding a "potential," which can be computed unambiguously from the Low equation, but which leaves the on-shell scattering intact in the limit when the off-shell extension (and hence the "potential") vanishes. The connection between this two-body off-shell model and a "three-body force" which leads to the same three nucleon observables can then be ambiguously constructed. Results from these further explorations will be presented.

---

[1]H. P. Noyes, in *Few Particle Problems*, edited by I. Slaus, *et.al.*, (North Holland, Amsterdam 1972) p. 122.

[2]H. P. Noyes, Phys. Rev. C26 (1982) 1858.

[3]H. P. Noyes and M. J. Orlowski, "Zero Range Scattering Theory III" (in preparation).

*Work supported by the Department of Energy, contract DE-AC03-76SF00515.

Submitted to the International Conference on Nuclear Physics Florence, Italy, 8/29 - 9/3, 1983